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# The Mystery of Monogamy

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*We examine why developed societies are monogamous while rich men throughout history have typically practiced polygyny. Wealth inequality naturally produces multiple wives for rich men in a standard model of the marriage market. However, we demonstrate that higher female inequality in the marriage market reduces polygyny. Moreover, we show that female inequality increases in the process of development as women are valued more for the quality of their children than for the quantity. Consequently, male inequality generates inequality in the number of wives per man in traditional societies, but manifests itself as inequality in the quality of wives in developed societies.* (*JEL* J12, J16, J24, Z13)

Throughout history, wealthy men have tended to mate with multiple wives. This practice, known as polygyny, exists in 850 of the 1,170 societies recorded in Murdock's Ethnographic Atlas (John Hartung 1982). Polygyny is still prevalent in much of Africa where the percent of women living in polygynous households ranges from 25 to 55 percent in the Western, Central, and Eastern parts (Ron Lesthaege 1986).

Moreover, polygyny is easy to explain. The standard approach to understanding polygyny comes from the "threshold model" in the biology literature (Gordon H. Orians 1969; Stephen T. Emlen and Lewis W. Oring 1977). This model is based on two assumptions: (a) males, in contrast to females, can increase their offspring by acquiring more mates; and (b) there is heterogeneity in male resources but no variation in female endowments. Under these assumptions, males with more resources acquire multiple female partners on the account of males with fewer resources. Economists have applied this model to humans by showing that male inequality in wealth produces inequality in the number of their wives (Gary S. Becker 1991; Ester Boserup 1970; Amyra Grossbard 1976; Shoshana Grossbard-Shechtman 1993). As a result, polygyny is considered a natural consequence of male inequality in wealth, combined with gender differences in the constraints on reproduction.

It is not well understood, however, why polygyny is virtually nonexistent in modern industrialized societies. Given the large and often staggering disparities in wealth in many highly developed countries, it is somewhat of a mystery that monogamy has emerged almost universally in the marriage market of advanced economies. The goal of this paper is to offer an explanation for the emergence of monogamy even in the presence of persistently high levels of income inequality.

A key insight of our model is that the increasing importance of human capital in modern economies generates increasing variation in the value of women in the marriage market, thus

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offsetting the effect of high male inequality on polygynous behavior. In particular, skilled men in modern economies increasingly value skilled women for their ability to raise skilled children, which drives up the value of skilled women in the marriage market to the point where skilled men prefer one skilled wife to multiple unskilled wives.

As a result, our model demonstrates that the incidence of polygyny depends on the sources of male inequality, not just the level. In general, income is derived from two sources: (a) labor income, which is a function of human capital; and (b) nonlabor income such as land, physical capital, and corruption. The model shows that the marriage market equilibrium becomes more monogamous as the level of inequality is determined more by disparities in human capital than by disparities in nonlabor income. This result is consistent with the idea that inequality in advanced economies is determined more by differences in human capital, while inequality in less-developed societies is primarily due to a skewed distribution of nonlabor income.[1]

The key assumption of the model is that high-quality men and women have a comparative advantage in raising higher-quality children, since they are more efficient in educating their children. Therefore, rich men in less-developed economies, who typically derive their wealth from nonlabor income, do not produce quality children efficiently. As a result, rich men in less-developed economies have a low demand for quality children, which translates into a low demand for quality in women in the marriage market. Hence, the value of women in the marriage market is determined by the quantity, rather than the quality, of children they can produce. Assuming that all women produce a similar expected number of children, all women are close substitutes for each other in the marriage market in primitive economies, which keeps the price low enough so that rich men can afford more than one wife. Consequently, rich men in developing economies marry multiple wives and have many children with low levels of human capital.

In advanced economies, human capital plays a larger role in determining the wealth of richer men. The importance of human capital in determining wealth implies that the cost of producing child quality is low relative to the return, which creates a high demand for child quality versus quantity. The increased demand for quality children increases the demand for quality in women in the marriage market, which stems from the increasing value of their input in producing child quality. As a result, the price of quality women increases, making polygyny less affordable for rich men who want high-quality wives.

In other words, male inequality generates polygyny, but female inequality reduces it. Our model shows how female inequality is generated in the marriage market. When human capital is a bigger factor in determining a child's future income, women who can create high-quality children more efficiently are increasingly valued in comparison to women who produce quality children at a higher cost. This inequality within women directly influences the degree of polygynous mating in equilibrium. As a result, male inequality in less-developed societies translates into inequality in the number of wives per man, while inequality in developed countries generates inequality in the quality of wives. Becker (1991) calls inequality in the quality of wives "implicit polygyny," which our model shows is the equilibrium outcome when the source of inequality stems mainly from human capital.[2]

[1] For example, labor income explains 72 percent of the variation in total income for male heads of households in the United States 1990 Census versus only 54 percent in the Permanent Interstate Committee for Drought Control in the Sahel (CILSS) data from Côte d'Ivoire in 1986. This notion is also consistent with the evidence that the negative effect of land inequality on growth is usually found to be stronger than income inequality. See Alberto Alesina and Dani Rodrik (1994) and Klaus Deininger and Lyn Squire (1998).

[2] Grossbard-Shechtman (1993) predicts that increasing the variation in female productivity in agriculture reduces polygyny in less-developed societies. But, this conjecture is not used to explain the correlation between development and polygyny.

Considering the prevalence of polygyny throughout history, the existing literature on this issue in economics is quite limited. Becker (1991) presents the classic model of the marriage market which allows for multiple partners, and shows that inequality in men naturally leads to polygyny. This model has been extended and tested empirically by Jack Goody (1963), Boserup (1970), Grossbard (1976), and Hanan G. Jacoby (1995). However, these models are rather specific to the setting of an agrarian economy, and tend to focus on the idea that wives are a source of labor. For example, Becker (1991) predicts that polygyny is positively associated with the increasing productivity of women in the output market. But, female productivity seems to be positively correlated with development, so this prediction appears to be inconsistent with the virtual extinction of polygyny in advanced societies.

There is surprisingly very little written about the correlation between monogamy and development in the social sciences. In the biological literature, monogamy in certain species like birds is often explained by the need for large paternal investments in the survival of offspring (Frank Marlowe 2000). Becker (1991) applies a similar idea to humans by arguing that the marginal productivity of men versus women in the production of children rises with development, which reduces the incidence of polygyny in advanced societies. Nils-Petter Lagerlof (2005) explains the decline in polygyny with the decline in male inequality—an idea advanced by Satoshi Kanazawa and Mary C. Still (1999) in the sociology literature. In the demography literature, the level of polygyny is explained by imbalanced sex ratios which may result from the natal sex ratio, the capturing of female slaves, male labor migration, and the higher male mortality rate from disease, warfare, and dangerous occupations such as hunting and fishing (Douglas R. White and Michael L. Burton 1988). Anthropologists have argued that monogamy is correlated with development since it is a product of egalitarianism (Richard D. Alexander 1987), or is a result of the need to placate poorer men in order to maintain the necessary level of social cohesion required for a modern industrialized economy (Laura Betzig 1986, 1995).

In contrast to the existing literature, we do not explain the transition to monogamy with declines in male inequality, increasingly balanced sex ratios, or changes in the roles of men and women in the raising of children. Modern societies still exhibit high levels of income inequality, and it is not clear why a poor woman would not prefer to be the second wife of a rich man even if the sex ratio is completely balanced, or how "egalitarianism" could prevent them from doing so. Moreover, rather than focusing on the differences between men and women in the production of children, we focus on the differences among women in their ability to raise high-quality children, since women are still overwhelmingly the primary caregivers in modern societies. As human capital becomes more important in the economy, we show that highly skilled women become more valuable in the marriage market relative to unskilled women, giving rise to monogamy even in the presence of high levels of male income inequality.

Finally, it is worth noting that monogamy is not just a mystery to economists. For example, anthropologist Laura Betzig frequently questions why monogamy is so strongly associated with development. Betzig (1991, 344) writes:

> That leaves me with my favorite question. When, and why did polygyny and despotism end, and monogamy and democracy begin? Some people have said the Roman Empire was monogamous. This evidence is not persuasive. Others have said monogamy began in the Middle Ages under the Catholic Church. But political, economic, and even reproductive inequality seem to have characterized medieval Europe too. It seems to me that one event changed all that: the switch to an industrial economy in Europe in the past few centuries.

This paper offers an answer to this question.

## I. The Model

In this section, we set up a general equilibrium model of the marriage market which allows for polygynous matching. The goal is to determine which factors push the equilibrium to be more polygynous or more monogamous, and to study under what circumstances monogamy can exist at all. The underlying mechanism is based on the interaction of polygynous mating with the trade-off between child quantity and child quality.

We consider an economy that produces a single homogeneous good, using efficiency units of labor as its sole input. Marriage occurs upon the consent of a man and a woman, and multiple partners are allowed. Every married woman gives birth to exactly two children, a boy and a girl, and the parents jointly determine their children's level of human capital as well as the division of consumption between each member of the household.[3]

### A. *Marriage*

A woman's utility level is determined by two components: (a) her personal life-long consumption, and (b) the level of human and physical capital that she and her husband provide for their children. A man can marry a woman if he provides her with the equilibrium utility level determined in the marriage market for her type. Thus, marriage in this setup is an agreement over the division of family resources between the husband, wife, and their children. Marriage is not restricted to be monogamous.

### B. *Production and Human Capital*

We assume that there are two levels of human capital, "skilled" and "unskilled."[4] A man's output, $x$, is equal to 1 if he is unskilled and equal to $h > 1$ if he is skilled. For a person to become skilled, his or her parents have to invest resources during their childhood in their human capital. However, skilled parents are assumed to be more efficient in the production of skilled children. That is, skilled men and women have a comparative advantage in producing skilled children.[5] Hence, if both parents are skilled, the combined cost of educating their two children is $\underline{e}$. If only one parent is skilled (either the father or the mother), the cost is higher and is denoted by $\bar{e}\,(\bar{e} > \underline{e})$. If both parents are unskilled, the cost is assumed to be prohibitively high so that both children will grow up to be unskilled. Note that if the parents decide to invest in their children's human capital, then both children become skilled adults.[6] Although we assume that the exact

[3] Although this formulation abstracts from the decision over quantity of children per wife, it captures the idea that while women face biological restrictions on child quantity, men can use polygyny as an instrument to increase child quantity.

[4] Throughout the analysis, the term "skill" will refer to the level of human capital and will be used interchangeably with the term "quality." In this sense, human capital should be thought of as both formal and informal schooling and training both inside and outside the home. Furthermore, human capital could be any skill which makes a person more productive in the formal labor market or informal agrarian sector. The crucial assumption is that human capital is determined by the investment decisions of the parents (not simply inherited from the parents) and that it has a positive effect on income and on the production of human capital in children.

[5] Theoretically, less educated parents who are less productive as educators could possibly rent teachers for their children. However, in a world where there are some frictions (due to moral hazard problems, income taxes, etc.), educated teachers are not perfect substitutes for the role of parents in the education of their children. The large body of empirical evidence consistent with this assumption includes Paul T. Schultz (1993), John Strauss and Duncan Thomas (1995), Joseph G. Altonji and Thomas A. Dunn (1996), David Lam and Suzanne Duryea (1999), Jere R. Behrman et al. (1999).

[6] Thus, we are abstracting from issues concerning how marriage markets may interact with a gender bias in favor of sons or daughters. See Lena Edlund and Lagerloff (2002) for an extensive analysis of some of these issues.

amount of human capital given to sons and daughters is the same, relaxing this assumption by assuming that their levels are positively correlated would not affect the qualitative results of the model. This assumption, together with the assumption of each woman giving birth to one boy and one girl, implies that there is an equal number of men and women in the population, and that the proportion of men and women who are skilled is identical. We denote this proportion by $\theta$.

For simplicity, we assume that men earn income in the labor market and women do not. The total income for a man, denoted by $I$, depends on his level of human capital $x \in \{1, h\}$, and the bequest he received from his parents $b_{-1}$. Thus, a man's income is: $I = x + b_{-1}$.

A man's budget constraint is given by

$$c + n(y + \varepsilon e + b) = I, \tag{1}$$

where $c$ and $y$ are the consumption levels of the man and each of his wives respectively, $n$ is the number of wives he marries, $\varepsilon$ is an indicator function for whether the couple has agreed to raise skilled children ($\varepsilon = 1$ if they raise skilled children and $\varepsilon = 0$ if they do not), $e \in \{\underline{e}, \bar{e}\}$ is the cost per wife of raising skilled children (which depends on his and his wife's human capital), and $b$ is the bequest level which represents a physical transfer of resources to the children of each wife. For the sake of being consistent with the assumption that women do not have income, we assume that bequests are allocated to boys.[7] We follow Becker (1991) by making the number of wives, $n$, a continuous variable. This assumption simplifies the analysis by avoiding corner solutions. A fraction of a wife can be considered the fraction of a man's lifetime that he is married to a wife.

Equation (1) shows that a man's income is divided between his own consumption, the consumption of each wife, human capital investments in his children, and bequest transfers to his children. Note that this formulation of the budget constraint indicates that although men are allowed to marry multiple wives, the terms of each marriage are identical for any given man in terms of the type of woman he marries, the bequest level for his sons, and the investment in human capital for each child. However, as will become apparent, a man will not be able to increase his utility in equilibrium by offering different contracts to multiple women of the same skill level, or by marrying women of different skill levels.

### C. *Preferences*

An individual's preferences are defined over their own consumption, the number of their children, the human capital of their children, and the future income of each son which consists of his human capital ($x \in \{1, h\}$) plus his bequest level, $b$. In particular, preferences are represented by the following utility function:

$$u = \ln c + \ln[n(x + b)]. \tag{2}$$

Thus, men and women have the same preferences, except that women are biologically constrained to have two children ($n = 1$), while men choose their quantity of children implicitly by choosing how many wives to marry, $n$.

[7] This assumption is consistent with the historical evidence (see Maristella Botticini and Aloysius Siow 2003).

### D. *Inequality*

While the results of the model hold in a dynamic overlapping generations model with an infinite horizon, we find it more transparent to present it in a static context here and present the dynamic extension in the Appendix. As we show in the dynamic extension, all unskilled men inherit the same bequest level regardless of their parents' human capital, henceforth denoted by $\lambda$, and all skilled men inherit the same bequest level, denoted by $L$.

Thus, an unskilled man's total income is $I_u = 1 + \lambda$ and a skilled man's income is $I_s = h + L$. Income inequality between skilled and unskilled men is represented by $g$:

$$g \equiv \frac{I_s - I_u}{I_u}.$$

The level of inequality $g$ has two sources: inequality from differences in human capital ($h$ relative to 1), and inequality which is due to disparities in nonlabor income ($L$ relative to $\lambda$). This setup allows us to analyze how the level and the composition of inequality influence the rate of polygynous matching in equilibrium. Furthermore, we assume that bequest levels are distributed in a way so that skilled men are richer than unskilled men ($g > 0$). In the Appendix, we show that when $g$ is determined endogenously in a dynamic model, it is indeed larger than zero.

## II. Analysis

DEFINITION: *Equilibrium in the marriage market is defined by (a) men maximizing their utility subject to their budget constraints taking women's utility for each type as given, and (b) the marriage market clears—all women get married.*

Each man chooses his consumption, $c$, the number of wives, $n$, the consumption level of each wife, $y$, the human capital level of each child, $\varepsilon$, and the bequest transfer to each son, $b$, so as to maximize his utility function in equation (2) subject to the budget constraint in equation (1) and given the equilibrium utility level of skilled and unskilled women, $u_s$ and $u_u$, respectively:

$$\max_{c,n,y,\varepsilon,b} \{\ln c + \ln[n(x+b)]\} \qquad \text{s.t. } c + n(y + \varepsilon e + b) = I, \qquad u_i = \ln y + \ln[(x+b)],$$

where $i = s, u$. It should be noted that the terms of the marriage contract between a husband and wife ($y, \varepsilon$, and $b$) are efficient, as men maximize their own utility for any given level of utility for each woman. Since all women get married and there are no frictions in the marriage market, male optimization implies that the equilibrium is efficient.

We now establish several basic results stemming from the man's optimization problem, while leaving the formal derivations for the Appendix. The consumption level of skilled men is:[8]

$$c = n(y + \varepsilon e + b) = (h + L)/2, \tag{3}$$

while the consumption level of unskilled men is:

$$c = n(y + \varepsilon e + b) = (1 + \lambda)/2. \tag{4}$$

[8] The proof is part of the proof of Lemma 1.

Therefore, half of a man's income is spent on consumption and half is spent on women and children. It also follows that:

LEMMA 1: *A woman's consumption level is*

$$y = \frac{x - \varepsilon e}{2}, \tag{5}$$

*where x (her children's human capital) equals* 1 *or h if* ε *equals* 0 *or* 1*, respectively, and e equals the cost of producing skilled children, which depends on her skill level and her husband's skill level* $(e \in \{\underline{e}, \bar{e}, \infty\})$.

For example, the consumption of a skilled woman who raises skilled children with a skilled man is $y = (h - \underline{e})/2$, while an unskilled woman who raises skilled children with a skilled man consumes $y = (h - \bar{e})/2$. All women who raise unskilled children receive $y = ½$. Therefore, a woman's consumption level is always equal to half the net value of her children's human capital. If she raises skilled children, her consumption level is half the difference between the value of skill, $h$, and the cost for that household to raise skilled children. The consumption level of a woman who raises unskilled children is also equal to half the value of unskilled human capital (normalized to equal one) minus the cost (which is zero).

The following lemma establishes the decisions of parents to invest in their children's human capital, as a function of the return to human capital and the skill level of each parent.

LEMMA 2: *If both parents are skilled, they raise skilled children if and only if* $h \geq \underline{h}$, *where* $\underline{h} \equiv 1 + \underline{e}$. *If one parent is skilled and the other is not, then they raise skilled children if and only if* $h \geq \overline{h}$, *where* $\overline{h} \equiv 1 + \overline{e}$.

The intuition underlying Lemma 2 is straightforward: parents raise skilled children if and only if the return to investing in human capital, $h - 1$, is larger than its cost ($\underline{e}$ if both parents are skilled or $\overline{e}$ if only one is skilled).

The first two lemmas and equations (3) and (4) imply that the husband's consumption, the wife's consumption, and the education level of their children are uniquely determined by the return to education, $h$, and the skill level of both parents. Therefore, along the contract curve between a husband and wife, adjustments to the equilibrium utility level of the wife ($u_s$ or $u_u$) are achieved by changes in the bequest level. If a man has to provide a higher level of utility to his wife, he will increase the bequest level by decreasing the number of wives.

We now turn to analyzing the general equilibrium of the model, characterized by male optimization and market clearing. First, we establish the equilibrium patterns of matching between the two types of men and women, and how this matching process interacts with decisions to invest in their children's human capital. It turns out that although skilled (rich) men always invest at least as many resources as unskilled men in the human capital of their children, they also marry at least as many women as unskilled men.

LEMMA 3: *Rich men have at least as many wives as poor men.*

Lemma 3 is consistent with the evidence that wealth is positively correlated with the number of wives in polygynous societies. Under the model's structure of a balanced sex ratio, the lemma implies that if polygyny exists, only rich (skilled) men are polygynous.

Given this result, the following propositions determine the degree of polygynous matching in the marriage market. In particular, we derive the conditions that give rise to a monogamous equilibrium. To do this, we take as given the level of inequality, costs of human capital, and the total income for men of each skill level, and see how changes in the composition of inequality (i.e., changes in $h$ as $g$ is held constant) determine the equilibrium rate of polygyny.

The first proposition describes the equilibrium when the value of human capital, $h$, is sufficiently low, signifying that rich men acquired their wealth primarily through their nonlabor income, $L$.

PROPOSITION 1: *If* $h < \underline{h}$ *then:*

(*i*) *The degree of polygyny is independent of h.*

(*ii*) *The rich/skilled men are polygynous.*

(*iii*) *No one invests in child quality.*

This proposition states that when the return to human capital (relative to the costs) is sufficiently low, richer men (skilled men) marry more wives than poorer, unskilled men. When the value of human capital is sufficiently low, skilled men are not interested in producing quality children even with high-quality women, who can produce high-quality children at the lowest cost. Therefore, women in the marriage market are valued only for the quantity of children they can produce, which is assumed to be identical. As a result, the ratio of wealth between skilled and unskilled men, $1 + g$, translates into the ratio of the number of wives between the two types of men when the return to human capital is low. Note that polygyny is the equilibrium outcome when the value of human capital is low, despite having a balanced sex ratio in the marriage market.

However, holding the level of inequality constant, Proposition 1 states that the degree of polygyny is independent of $h$, implying that the rate of polygyny depends only on the level of inequality, not the composition of inequality. The quantity of wives that rich men can afford is determined by the uniform price for all wives in the market, which is determined by the aggregate level of income in the economy, not the different sources of income.[9] Therefore, the differences in total income between rich and poor men determine the differences in their number of wives and, thus, the rate of polygyny. Since Proposition 1 holds the level of inequality and the incomes of both types of men constant as $h$ changes, the degree of polygyny is constant as long as $h < \underline{h}$. This result is depicted in Figure 1A, which shows the number of wives for skilled and unskilled men as a function of $h$.

We now discuss the case where the value of human capital is sufficiently high so that $\underline{h} \leq h < \overline{h}$. As we will discuss in the next section, this is the range of $h$ that is likely to emerge in a steady state. Our analysis will focus on this range when discussing the main implications of the model.

PROPOSITION 2: *If* $\underline{h} \leq h < \overline{h}$, *then:*

(*i*) *The degree of polygyny declines with h.*

[9] Because all women raise unskilled children and the consumption transfer is always determined by the quality of their children, the consumption transfer is independent of the level or composition of aggregate income when the value of human capital is sufficiently low ($h < \underline{h}$). However, while bequests are not dependent on the composition of income in this region, they do increase with aggregate income. Thus the "full price" of a wife (the wife's consumption plus the bequest plus investment in the human capital of her children) is increasing with aggregate income in the economy.

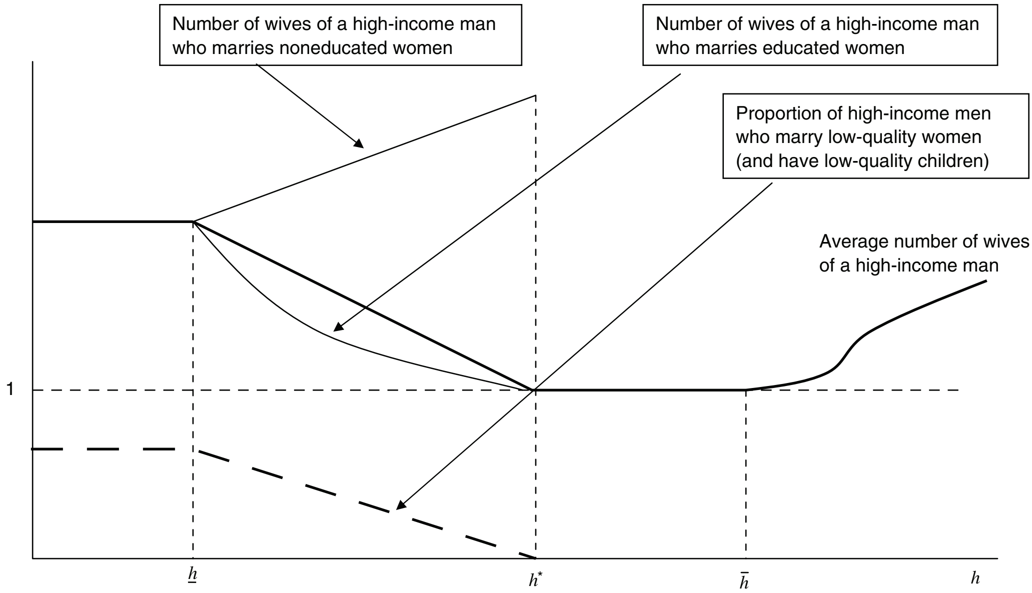


Figure 1A. Polygyny as a Function of the Value of Human Capital: Average Number of Wives of a High-Income Man

*Note:* The figure is plotted for the case where Proposition 3 is satisfied and monogamy exists.

(*ii*) *Skilled men who marry skilled wives invest in child quality, while skilled men who marry unskilled wives do not invest in child quality.*

Proposition 2 states that polygyny cannot be ruled out even when the value of human capital is sufficiently high to entice skilled men to raise quality children with skilled women. When the value of human capital is above $\underline{h}$, it is efficient for skilled men to invest in child quality, but only with skilled women who have a comparative advantage in producing quality children over unskilled women (see Lemma 2). As a result, skilled and unskilled women differ in the type of children they raise when $h$ lies within this region, so the value of skilled women in the marriage market is not identical to unskilled women (see equation (5)). Thus, skilled women are valued for the quality and not just the quantity of children they produce.

Figure 1A shows that some skilled men marry a certain number $(\geq 1)$ of skilled women and have skilled children, while other skilled men marry a greater number of unskilled women and raise unskilled children. The reason the latter group members marry a larger number of women is because they are being compensated for the lower-quality children with higher quantity. This result is enabled by the lower cost of unskilled women in equilibrium—the "full price" (the consumption transfer plus bequest level and human capital investment) is lower for unskilled women because of the low human capital of their children. In equilibrium, skilled men are indifferent between choosing either the "quantity" or "quality" strategy.

Proposition 2 also states the key result of the model: the rate of polygyny depends on the composition of income and inequality, and not just the levels. Figure 1A shows that as $h$ increases, holding constant the incomes of skilled and unskilled men, the average number of wives per skilled man declines. Interestingly, as $h$ increases in this region, the skilled men who marry unskilled women and raise unskilled children marry more and more wives relative to the skilled men who go for "quality." However, there are fewer and fewer skilled men who go for "quantity" as the value of quality increases with $h$. Thus, the skilled men who marry the unskilled women need to be compensated with more and more quantity. But, since fewer skilled men are going for "quantity," the average number of wives per skilled man declines over this region of $h\,(\underline{h} \leq h < \overline{h})$. Therefore, the rate of polygyny declines as the value of human capital increases, even after holding constant the level of income and inequality between the two types of men.

The intuition for this result stems from the increasing value of child quality, and consequently, the increasing demand for quality in women as the value of human capital increases. The return to investing $\underline{e}$ and having a skilled child with a skilled wife is increasing with the value of human capital $h$. But, because skilled men will raise skilled children only with skilled women (see Lemma 2), the demand for skilled women increases relative to unskilled women as $h$ increases within this region. Income levels are held constant throughout this exercise, so skilled men can afford fewer and fewer skilled women as their price increases with $h$. Thus, the rate of polygyny falls as income is determined more and more by human capital and less by nonlabor income.

Therefore, one of the main implications of the model is that while male inequality creates polygyny, female inequality reduces it. As $h$ increases, male inequality is increasingly determined by differences in human capital, and the value of quality in children also rises. As a result, the demand for quality women increases, since they are a complementary factor in the production of quality children. Thus, variation in the quality of women translates into inequality in the value of women (as indicated in Figure 2), making it too expensive for rich men to afford multiple wives of high quality. Therefore, male inequality stemming from differences in human capital translates into inequality in the quality, not the quantity, of their wives. Becker (1991) calls this "implicit polygyny," in recognition of the trade-off in the quantity and quality of wives. Our model shows that the degree of implicit versus explicit polygyny depends crucially on the sources of male inequality.

A further result of the model when $\underline{h} < h < \overline{h}$ is that there will be higher rates of assortative mating between men and women according to their skill level as $h$ increases. This is true because the number of skilled men who marry unskilled women declines with $h$ over this region, as more skilled men prefer to have skilled children with skilled women. This result is consistent with Raquel Fernandez, Nezih Guner, and John Knowles (2005), who show that the degree of assortative matching by education levels increases with the return to human capital in advanced countries.[10] Therefore, our model correctly predicts that the rate of assortative matching across quality levels of men and women will be related to the value of human capital.

Since skilled men marry fewer wives as inequality is determined more by human capital, it must also be the case that the number of wives per unskilled man increases with $h$ over the region where $\underline{h} < h < \overline{h}$ (see Figure 1A). This result stems from the declining demand by skilled men for unskilled women, lowering the price of unskilled women and making them more affordable for unskilled men.[11] The equilibrium tends to be more monogamous as $h$ increases over this region, but reaching a monogamous equilibrium is not guaranteed for all parameter values. A necessary, but not sufficient, condition for monogamy is that $\underline{h} < h < \overline{h}$, so monogamy cannot

[10] It should be noted that Fernandez, Guner, and Knowles (2005) restrict their analysis to developed countries that are monogamous. Interestingly, they show that the return to human capital is significant in determining how important it is for educated men to match with educated women, which implies that educated men and women do not match simply because they "have good conversation," which should be independent of the return to human capital. The fact that matching based on quality is related to the return to quality is consistent with our model.

[11] The "price" for unskilled women in terms of the consumption transfer is constant over the region where $\underline{h} < h < \overline{h}$, because the value of unskilled children is constant. However, the "full price" of unskilled women includes the bequest levels, which are falling as $h$ increases over this region. Thus, the full price of unskilled women decreases over this region, because of the declining demand for unskilled women by skilled men as $h$ increases.

occur if $h$ is too low or too high relative to the costs of human capital. Under certain conditions, the outcome could be monogamous for a sufficiently high level of $h$, denoted by $h^*$. The existence of $h^*$, as established in the following proposition, depends on the levels of inequality within men and women.

PROPOSITION 3: *If* $\underline{h} < h < \overline{h}$ *monogamy exists if and only if:*

$$\overline{e} - \underline{e} \geq g.$$

The left-hand side of the equation in Proposition 3, $\overline{e} - \underline{e}$, measures the comparative advantage of skilled women in raising skilled children. If there were no differences in the costs of producing quality children between skilled and unskilled women, this term would be zero and all women would be equal in the marriage market, leading to polygyny. The right-hand side of the equation, $g$, is male income inequality. If there is more income inequality among men, the likelihood that monogamy will characterize the equilibrium decreases. If the conditions for Proposition 3 hold, then the economy is monogamous for all values of $h$ between $h^*$ and $\overline{h}$, where $h^* \equiv 1 + g + \underline{e}$.

Proposition 3 essentially states that monogamy can exist only if the comparative advantage of skilled women in producing skilled children is large enough in relation to the relative wealth of the rich men in the economy. That is, higher male inequality generates more polygyny, since rich men will use their wealth to acquire more wives and children. But, a larger comparative advantage for skilled women generates higher inequality for women in their value on the marriage market, thus making polygyny less affordable for rich men who want quality wives. So, Proposition 3 basically emphasizes our previous results: male inequality generates polygyny, while female inequality generates monogamy. If the condition for monogamy does not hold ($\overline{e} - \underline{e} < g$), then Proposition 2 still holds, as depicted in Figure 1B.

The welfare effects of the transition from polygyny to monogamy as $h$ increases in the range of $\underline{h} < h < \overline{h}$ are as follows: the value of skilled women in the marriage market increases with the value of their children's human capital, and, therefore, the welfare of skilled women increases with $h$. Also, as $h$ increases, we know that unskilled men are able to marry more unskilled women, since the economy is becoming more monogamous. Therefore, the cost of marrying an unskilled wife must be declining for unskilled men, thus making unskilled men better off, but leaving unskilled women worse off.[12] Finally, there are two opposing effects on the welfare of skilled men. On the one hand, they marry fewer skilled wives and have fewer skilled children, but, on the other hand, each child receives a higher value for their human capital as $h$ increases. Nevertheless, we know that the latter effect dominates the first because skilled men are able to acquire a larger number of unskilled wives than they were able to marry before the increase in $h$, since the cost of unskilled women is declining.[13] Therefore, the welfare of skilled men also rises with $h$.

[12] Although the consumption transfer to an unskilled woman, ½, remains the same over the entire interval of $h$, the bequest that their children receive is declining.

[13] As indicated, a decrease in the cost of unskilled women (for skilled and unskilled men) is achieved by a lower bequest level for the children. Therefore, a lower cost of unskilled women has two opposing effects on welfare as well: (a) a lower cost enables both types of men to acquire more wives and children, but (b) a lower bequest for the children lowers utility for both types of men. The former effect dominates the latter so that welfare increases for both types of men when the cost of unskilled women declines. We know this because both types of men could always decrease the number of unskilled wives and increase the bequest (increasing the welfare of unskilled women) but they choose not to do so in equilibrium, which means that this is not optimal for them.

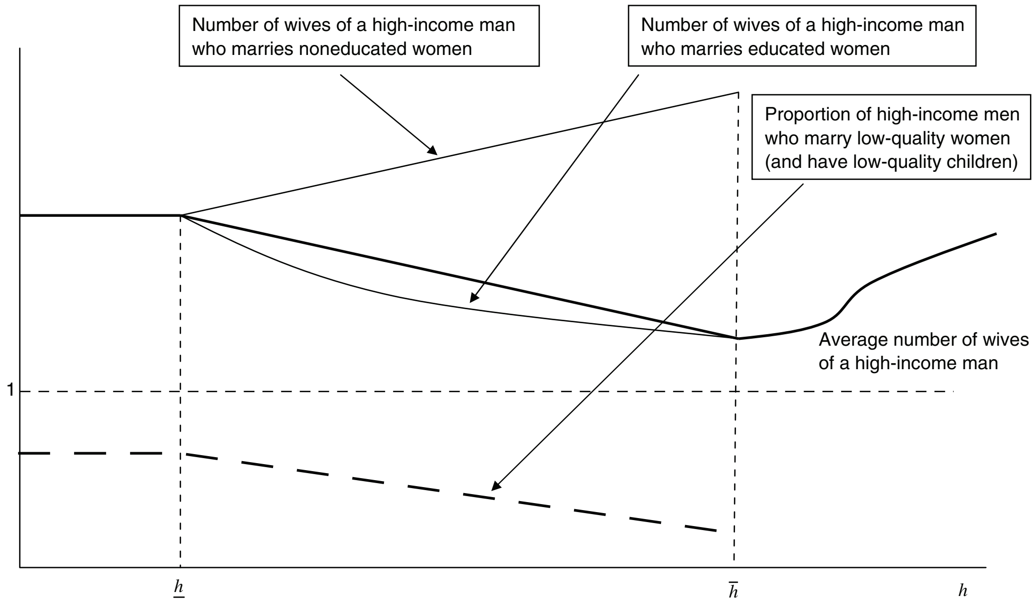


FIGURE 1B. POLYGYNY AS A FUNCTION OF THE VALUE OF HUMAN CAPITAL: AVERAGE NUMBER OF WIVES OF A HIGH-INCOME MAN

*Note:* The figure is plotted for the case where the condition in Proposition 3 is not satisfied and monogamy does not exist.

To summarize the welfare results, everyone benefits as $h$ increases except for unskilled women. This result is due to the increasing segmentation in the marriage market as the economy becomes more monogamous. As $h$ increases, skilled men increasingly prefer to marry skilled women in order to enjoy the higher value of skilled children, and this means that unskilled men face less competition in the marriage market from skilled men for unskilled wives. As a result, only unskilled women are hurt by their declining demand in the marriage market. Interestingly, these results appear to be inconsistent with the literature which frequently regards declining polygyny as harmful to rich men and a "gift" to poor men.[14] According to our model, this is true if polygyny is exogenously reduced (e.g., by law), but a decline in the equilibrium level of polygyny as $h$ increases is shown to benefit all men. Regarding women, our model is consistent with the belief that monogamy hurts women with lower marriage prospects and benefits women at the higher end. But, we show that this is true in the case that polygyny is eradicated endogenously as $h$ increases, and not just as a result of an institutional change.

We now briefly analyze the case where $h > \overline{h}$; however, we argue below, that this range is not likely to be relevant for the comparison between developed and less-developed countries.

PROPOSITION 4: *If* $h \geq \overline{h}$, *then:*

(*i*) *All skilled men invest in child quality, regardless of the skill level of their wives.*

(*ii*) *Skilled men are polygynous.*

[14] For example, see Becker (1991), Betzig (1986), and Alexander (1987).

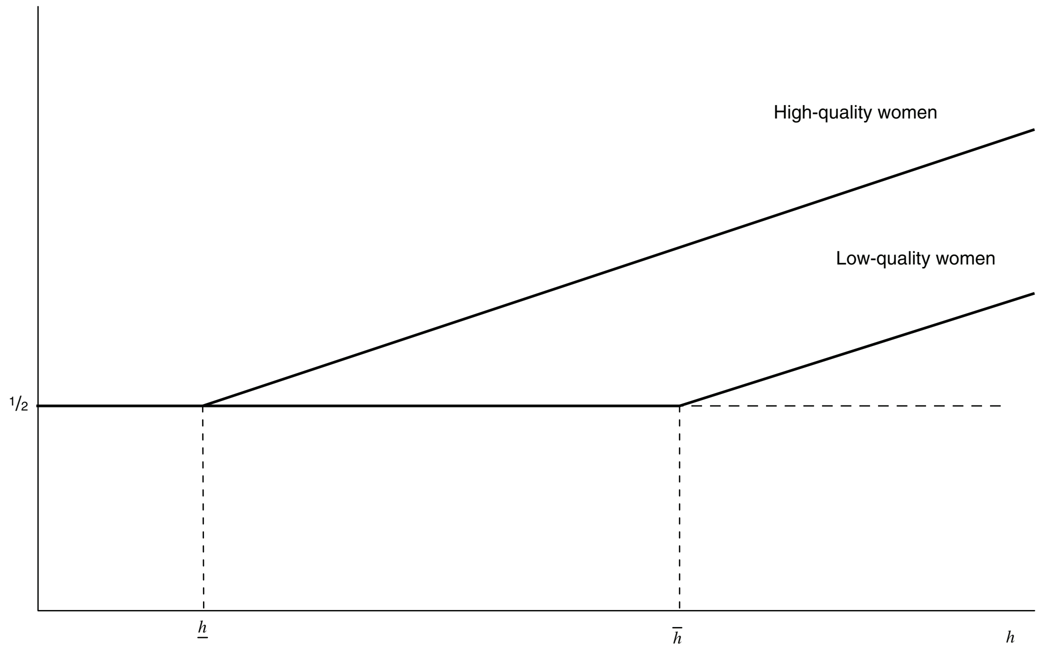


FIGURE 2. "CONSUMPTION PRICES" FOR BOTH TYPES OF WOMEN AS A FUNCTION OF THE VALUE OF HUMAN CAPITAL

(*iii*) *The degree of polygyny increases with h.*

When the value of human capital exceeds $\bar{h}$, it is now efficient for skilled men to have skilled children with either skilled or unskilled women (see Lemma 2). So, when $h$ is sufficiently high, unskilled women are also valued for the skilled children they are able to produce. Therefore, the value of skilled women in the marriage market falls relative to unskilled women when $h$ increases above $\bar{h}$. When $h$ is below $\bar{h}$, skilled women could extract the increasing value of human capital as $h$ increases for themselves and their children, because the value of their ability to produce quality children increased relative to unskilled women. But, when $h$ is above $\bar{h}$, skilled women no longer are necessary to produce skilled children, and they become increasingly substitutable with unskilled women as $h$ increases, since skilled men are increasingly willing to marry unskilled women despite the higher costs of producing skilled children. Therefore, the comparative advantage of skilled women in producing skilled children declines with $h$, which implies that the relative price of skilled women falls with $h$.

Essentially, the market power that skilled women have when $h$ is below $\bar{h}$, is transferred to skilled men when $h$ is above $\bar{h}$, since skilled men are the scarce resource needed to produce quality children in this range. Therefore, as $h$ increases in this region, all women are willing to sacrifice more in terms of their children's bequest in order to have skilled children with skilled men, so that their children can benefit from the higher level of $h$. It follows from Proposition 4 that the full cost for each type of woman (consumption transfer, cost of education, and bequest) declines with $h$ for skilled men as they acquire more wives, despite the fact that only the composition of income has changed, and not the levels.

The flip side of the story is that unskilled men marry fewer and fewer women as $h$ increases above $\bar{h}$. The model assumes that it is prohibitively expensive for unskilled men to have skilled children with unskilled women, so in order to compensate unskilled women for not having skilled children when the value of skill is very high, unskilled men have to increase the bequests to their children as $h$ increases. Thus, the full price of unskilled women who have unskilled children (the consumption transfer plus bequest) is increasing over this region, making it more expensive for unskilled men to acquire a wife. Therefore, polygyny increases as skilled and unskilled men increasingly compete for the same women, and skilled men exploit their comparative advantage in producing skilled children by acquiring more and more wives.

Finally, we conclude this section by discussing how polygyny is affected by the overall level of inequality. The entire analysis in Propositions 1–4 held the total level of income for each group, and, consequently, the level of inequality between the groups, constant as $h$ was free to vary. Holding $h$ constant, the following proposition varies the level of inequality.

PROPOSITION 5: *Given h, the degree of polygyny increases with male income inequality, g.*

This proposition states that increases in inequality resulting from increasing disparities in nonlabor income increase polygyny. The converse, however, is not true: increases in inequality stemming from bigger disparities in the value of human capital (i.e., $g$ increases due to a higher $h$) will increase polygyny if $h < \underline{h}$ or $h > \overline{h}$, but polygyny may or may not increase if $\underline{h} < h < \overline{h}$ (see equation (A16) in the Appendix). This ambiguity is due to two opposing effects: (a) an increase in inequality tends to make men more polygynous, and (b) an increase in the composition of wealth derived from human capital decreases polygyny. Therefore, the total effect on polygyny depends on which effect dominates. All of these results together show that the degree of polygyny is dependent not only on the level of inequality, as emphasized in the existing literature, but also the composition of inequality. Both of these factors determine whether male inequality manifests itself as inequality in the number of their wives, or the quality of their wives.

Before turning to the main implications of the model, we briefly discuss the importance of the various assumptions. The critical assumption of the model is that women differ in their efficiency in raising skilled children. Therefore, as the return to human capital rises, the variance in the value of women in the marriage market increases as women who can produce skilled children efficiently become less substitutable with less efficient women. This insight would not be affected if there is a continuum of skill levels for men and women instead of two levels. If skill levels are continuous, differences across women in their ability to produce higher-quality children should be increasingly rewarded in the marriage market when the return to human capital increases, thus reducing the substitutability of women with different abilities in creating children with higher levels of skill.[15] Therefore, as $h$ increases, men with higher levels of skill would become increasingly indifferent between marrying a smaller number of higher-skilled women and a fixed number of unskilled women. That is, society would still become less polygynous as human capital becomes more important in generating income and inequality.

In addition, if fertility is endogenous, we could model the comparative advantage of skilled women in raising skilled children by assuming that skilled women can produce more skilled children than an unskilled woman. In this setup, a rise in the returns to skills, which implies a rise in the demand for quality children, would increase the demand for higher-quality women. As a result, the price for quality women would increase, thus reducing the degree of polygyny in the economy. Also, the model could be extended to include genetic ability as a skill that

[15] Suppose that there is a continuum of women who differ in their cost of raising skilled children, and let $e_i$ be the cost for woman $i$. Following Lemma 1, a woman receives ½ as consumption if she raises unskilled children and $(h - e_i)/2$ if she raises skilled children. It can be shown that for $h$ between $1 + e_h$ and $1 + e_l$, the variance in consumption transfers to women strictly increases with $h$, where $e_h$ and $e_l$ are the cost of raising skilled children for the most and the least efficient woman, respectively.

is valued in women in the marriage market, since higher-quality genes are likely to be transferred to her children. In this case, the process of development should still generate increasing variation in the value of women in the marriage market, as long as acquired skills are positively correlated with good genes and the returns to both types of skills are positively correlated as well. These conditions seem reasonable, so including genetic ability in the model should still produce increasing female inequality, and thus lower polygyny, as human capital becomes more important. Therefore, the key results of the model seem robust to relaxing the main simplifying assumptions.

## III. Why Are Developed Countries More Monogamous than Less-Developed Countries?

In the context of the model, we can think of a developed country as having a high value of human capital $h$ relative to the costs of producing human capital ($\overline{e}$ and $\underline{e}$), compared to poorer countries. As discussed above, $h$ represents both the return and the level of human capital. Thus, in developed countries, $h$ can be associated with a college degree whereas an unskilled worker can be associated with a high-school dropout. In a poor economy, $h$ can represent a worker who graduated elementary school, while an unskilled worker is literate at most. Under this interpretation, $h$ is likely to be lower in developing countries. A higher rate of child mortality in poor countries would also contribute to a lower $h$, since this reduces the expected return to investing in education.[16] One might also think that the cost of becoming skilled is higher in advanced economies. However, the ratios of $h$ to $\overline{e}$ and $\underline{e}$ are likely to be higher in the advanced economy, because parents with higher levels of human capital are more effective in producing quality children (see Moav 2005).

Over time, $h$ is likely to converge to the second range of Figures 1A and 1B $(\underline{h} < h < \overline{h})$ if the return to skill is determined in the labor market by its marginal product and there is some degree of complementarity in the aggregate production process between skilled and unskilled workers. If $h < \underline{h}$, no one will invest in high-quality children and, therefore, the return to quality would rise so that $h$ will increase to a level above $\underline{h}$. On the other hand, $h$ larger than $\overline{h}$ implies that the supply of skilled workers increases over time, because unskilled women produce skilled children, thus reducing the return to skill until the economy reaches a steady state in which $h$ is no longer larger than $\overline{h}$. Thus, $h$ is likely to be of intermediate values $(\underline{h} < h < \overline{h})$ in any steady state. Therefore, we focus the analysis on this region throughout the paper.

Restricting our attention to this region of $h$ $(\underline{h} < h < \overline{h})$, $h$ in poorer countries is likely to be closer to $\underline{h} = 1 + \underline{e}$, while $h$ in richer countries is likely to be closer to $\overline{h} = 1 + \underline{e}$. According to Proposition 2, this implies that richer countries should be more monogamous, since inequality is determined more by differences in human capital, while inequality in poorer countries is determined more by differences in nonlabor income (land, physical capital, corruption, etc.).[17] As a result, male inequality in poorer countries tends to manifest itself as inequality in the number of wives per man, while male inequality in advanced countries translates into higher inequality in the quality of wives per man.

It should be noted that a standard model of fertility (e.g., Becker and Gregg H. Lewis 1973) could generate an increase in child quality and a reduction in child quantity in the process of development. This transition could be interpreted as a reduction in the demand for wives which

[16] The decline in child mortality in the process of development could be captured as an increase in $h$ in the model and, thereby, contribute to the transition to monogamy.

[17] The overall level of inequality is usually higher in poorer countries, so this may also contribute to their higher rates of polygyny (see Lagerlof 2005). Also, see footnote 1 in the introduction for evidence that inequality is more dependent on human capital in advanced countries.

reduces the demand for polygyny. However, in the context of an explicit two-sided marriage market model, a lower demand for wives will lead to a lower equilibrium price, thus producing an offsetting effect on the demand for multiple wives. Therefore, the shift toward quality children in developed countries does not necessarily lead to a more equal distribution of wives across men in equilibrium.[18] Our analysis demonstrates how a quality-quantity trade-off model can produce a more monogamous equilibrium in the process of development, by generating a concurrent increase in the inequality of women in the marriage market. In contrast to existing models of fertility, the rise in the demand for child quality generates a competition for child inputs, in particular skilled women, which results in a more monogamous equilibrium.[19]

An alternative approach for comparing developed to less-developed countries would be to examine differences in the proportion of rich men who are rich because of their human capital versus rich men who are wealthy because of their nonlabor income. That is, we could extend the model to allow for two types of rich men, and developed countries would be characterized by having a greater proportion of rich men who acquire their wealth through human capital. In this framework, it is straightforward to show that the rate of polygyny would decline with development (i.e., with increases in the proportion of rich men who are skilled), as predicted by the current setup of the model.

## IV. Conclusion

This paper uses standard assumptions regarding preferences and the production of human capital to explain why modern societies are less polygynous than less-developed societies. As such, this paper is part of an emerging literature which examines the interaction of growth, development, and marriage patterns.[20]

The model explains why men in less-developed economies prefer quantity over quality in wives and children, and derives the marriage market equilibrium which allows them to afford multiple wives. The explanation is rather intuitive. Rich men in less-developed economies are not efficient at producing quality children because they tend not to have high human capital themselves. Therefore, they have a low demand for quality children and, consequently, a low demand for quality women who can help them produce quality children. As a result, women in less-developed societies are valued only for the quantity of children they can produce, and not the quality. This makes all women very close substitutes for one another, which keeps the price of all women low enough for richer men to acquire multiple wives.

In more advanced economies, richer men tend to have high human capital and, therefore, they are more efficient at producing human capital in children. This creates a high demand for quality in children and in women, because quality women are complements in the production of high-quality children. Thus, all women are not close substitutes in the marriage market in advanced societies. Higher-quality women are a scarce resource, which drives up their price in the marriage market and makes polygyny less affordable for wealthy men.

[18] In addition, the prediction that wives are cheaper in advanced societies seems inconsistent with the idea that a husband and wife generally split household resources more equally in modern societies. In contrast, our model predicts that monogamy is a sign that wives are becoming more important and expensive in the process of development.

[19] See Becker and Lewis (1973); Becker, Kevin M. Murphy, and Robert Tamura (1990); Oded Galor and David N. Weil (1996); Galor and Moav (2002); Moav (2005); and Matthias Doepke and Fabrizio Zilibotti (2005), among others.

[20] See Michael Kremer (1997); Rao S. Aiyagari, Jeremy Greenwood, and Guner (2000); Edlund and Lagerlof (2006); Guner (1999); Fernandez and Richard Rogerson (2001); Fernandez, Guner, and Knowles (2005); and Michèle Tertilt (2005, 2006).

The main implication of the model can be summarized as follows: male income inequality generates polygyny, but female inequality in the marriage market reduces it. Moreover, the model shows how female inequality is generated in the marriage market equilibrium. As the return to human capital increases, women who can create high-quality children more efficiently are increasingly valued in comparison to low-quality women.

The model yields several testable predictions. The main empirical prediction is that the composition of inequality, not just the level, is an important determinant of the degree of polygyny in society. Specifically, societies should be more polygynous in countries where variation in overall wealth inequality is determined more by differences in nonlabor income (capital and inherited wealth) versus income variation generated by differences in the levels and returns to human capital investments.

Also, the model generates predictions regarding how the two sources of income inequality affect the overall patterns of assortative mating between husbands and wives. The existing literature (e.g., Fernandez, Guner, and Knowles 2005) is consistent with our model by showing that increases in the returns to human capital generate a higher rate of assortative mating based on education levels. However, the existing analysis is restricted to advanced countries which are monogamous. If polygynous societies could be included in the analysis, then assortative mating between husbands and wives could be examined across two dimensions: the education level of each spouse (the quality of each spouse) and the quantity of spouses. Our analysis predicts that these two dimensions interact with one another—the process of development increases a wealthier man's tendency to marry fewer, higher-quality wives versus multiple, lower-quality wives. Also, our model predicts that rich men in polygynous countries should exhibit a negative correlation between quality and quantity of wives, and the wealthy men who choose to marry fewer, but higher-quality, wives should also produce higher-quality children.

Another general implication of the model is the idea that women are rewarded in the marriage market in advanced countries for the quality of children they can produce. This idea yields several testable implications regarding the importance of a mother's education level in producing educated children, and whether the bargaining power of a wife within the marriage increases with the quality of her children.

Finally, we conclude by discussing the policy implications of our results. The most obvious policy instrument is a ban on polygyny, which would essentially force wealthy men to invest in child quality rather than acquiring multiple wives and lots of children (see Tertilt 2005, 2006). However, bans on polygyny are difficult to enforce and often ignored, as they are in Western Africa today.[21] In developed countries, bans on polygyny seem to be effective, but this is most likely due to the low demand for polygyny in equilibrium. In this sense, we follow the line of reasoning in Becker (1991) and Jon Elster (1989) by arguing that laws and norms may effect behavior, but they rarely evolve if personal incentives are weak to uphold them. Our model should be considered an attempt to explain how personal incentives to become polygynous decline naturally with development and, therefore, align themselves with laws and norms to reinforce a monogamous outcome. A second policy instrument is a simple subsidization of education. The subsidy will have not only a direct effect of encouraging increasing investments in education, but also an indirect effect of encouraging monogamy—since the higher net value of education will

[21] Some may argue that monogamy is explained by bans on polygynous behavior in various societies throughout history (the Romans and the Christian Church). It is beyond the scope of the paper to answer why certain societies passed laws against polygyny exactly when they did and why others did not. Our goal is to understand why developed societies are more monogamous than less-developed societies. It is worth noting, however, that many sociologists and anthropologists believe that prohibitions against polygyny by the Romans and the Christian Church did not produce monogamous practices in terms of mating with only one woman. See Lawrence Stone (1977), Georges Duby (1983), Goody (1983), Pierre Grimal (1986), and Betzig (1991, 1995).

increase the payoff of investing in quality women and children. In turn, increasing monogamy can help create or reinforce a monogamous norm, which then leads to more investments in child quality and more growth and development to follow.

## Appendix A: Proofs

This Appendix presents the proofs for the main results, lemmas, and propositions in the main text. In particular, we solve for the equilibrium consumption levels and child bequests received by skilled and unskilled women in the marriage market, which depend on whether or not they raise skilled children. In addition, we sketch out a dynamic extension of the model.

*Notation.*—Let $y_{ss}$ and $y_{us}$ denote the consumption of a skilled and unskilled woman, respectively, who marries a skilled man and raises skilled children. Let $y_{su}$ and $y_{uu}$ be the consumption of a skilled and unskilled woman, respectively, who raises unskilled children. We denote by $n_{ij}$ the number of women with skill level $i \in \{s, u\}$ that a skilled man marries, with each wife producing children of skill level $j \in \{s, u\}$. We denote by $v$ the number of wives an unskilled man marries (as we show below in equilibrium, unskilled men marry only unskilled women and produce only unskilled children). Similarly, we denote by $b_{ij}$ the bequest endowed to each son of a woman with skill $i$ that raises children with skill $j$. Finally, in the proofs of Propositions 2 and 4, we find it useful to define $r \equiv 1/(1+g)$, where $g$ is defined in the main text to be the level of male income inequality.

PROOF OF LEMMA 1 (Deriving $y$):

Given $u_s$ and $u_u$, the equilibrium utility level of skilled and unskilled women, respectively, every man chooses the optimal combination of number of wives, type of wives, consumption transfer to each wife, education level of the children, and bequest level to his sons. Formally, he chooses $n$, $i$, $y$, $\varepsilon$, and $b$ to maximize equation (2) subject to equation (1) and the following constraint:

$$\ln y + \ln(x+b) \geq u_i, \tag{A1}$$

where $u_i \in \{u_s, u_u\}$.

Men's optimization requires that equation (A1) hold with equality. Hence,

$$y = \frac{U_i}{x+b}, \tag{A2}$$

where $U_i \equiv \exp u_i$. Substituting equations (1) and (A2) into equation (2) yields

$$\max\left\{\ln\left[I - n\left(\frac{U_i}{x+b} + \varepsilon e + b\right)\right] + \ln[n(x+b)]\right\}.$$

Deriving first-order conditions with respect to $n$ and $b$, respectively, produces the following conditions after rearranging:

$$I = 2n\left(\frac{U_i}{x+b} + \varepsilon e + b\right), \tag{A3}$$

$$I = n(x + \varepsilon e + 2b). \tag{A4}$$

Substituting equations (1) and (A2) into equation (A3) yields equations (3) and (4). Substituting equations (A2) and (A4) into equation (A3) and rearranging yields

$$y = \frac{x - \varepsilon e}{2},$$

which proves Lemma 1.

PROOF OF LEMMA 2:

Consider a couple composed of two skilled parents, and let $x$ and $b$ denote the equilibrium skill and bequest levels, respectively. Recall that their cost of raising skilled children is $\underline{e}$ and the difference in income between skilled and unskilled children is $h - 1$. Consider the case where $h - 1 < \underline{e}$. If $x = h$, then $x + b$ can be increased without affecting $c$ and $n$ by setting $x = 1$ and increasing $b$ by $\underline{e}$. Therefore, if $h - 1 < \underline{e}$, $x = h$ is not optimal and thus cannot be an equilibrium.

Suppose that $h - 1 > \underline{e}$ and $x = 1$. In this case, $x + b$ can be increased without affecting $c$ and $n$ by setting $x = h$ and reducing $b$ by $\underline{e}$. Hence, if $h - 1 > \underline{e}$, $x = 1$ is not optimal and cannot be an equilibrium. Whenever $h = \underline{e} + 1$, parents are indifferent between $x = 1$ and $x = h$, in which case we assume that they raise skilled children. Thus, we have shown that if both parents are skilled, they raise skilled children if and only if $h \geq \underline{h}$.

If only one parent is skilled, the cost of raising skilled children is $\overline{e}$. We can use the same argument to show that if one parent is skilled and the other is not, they raise skilled children if and only if $h \geq \overline{h}$. This completes the proof of Lemma 2.

PROOF OF LEMMA 3:

First, let us consider the case in which skilled and unskilled men raise unskilled children, and denote by $v$ the number of wives that each unskilled man marries. According to equation (5), the consumption of women is ½ regardless of the man's type. Since men value all women identically, their children receive the same level of bequest. Hence, equations (3) and (4) imply that $n_{iu} = (1 + g)v > v$, proving the lemma for this case.

Now, consider the case where at least some skilled men raise skilled children, and assume by contradiction that $v > n_{is}$. There are two alternatives: (i) unskilled men who marry skilled women raise unskilled children, or (ii) at least some unskilled men raise skilled children.

In alternative (i), it must be the case that skilled women are indifferent between marrying skilled men and raising skilled children and marrying unskilled men and raising unskilled children. Hence, by equation (5),

$$\ln\left(\frac{h - \underline{e}}{2}\right) + \ln(h + b_{ss}) = \ln\left(\frac{1}{2}\right) + \ln(1 + b_{su}).$$

Due to Lemma 2, it must be the case that $h \geq \underline{h} = 1 + \underline{e}$. As a result, it follows that $(h - \underline{e})/2 \geq$ ½, and, therefore, $h + b_{ss} \leq 1 + b_{su}$.

On the other hand, since at least some skilled men raise skilled children, it follows that

$$n_{ss}(h + b_{ss}) \geq n_{su}(1 + b_{su}) = (1 + g)v(1 + b_{su}) > v(1 + b_{su}),$$

where the equality stems from equations (3) and (4). Combined with $h + b_{ss} \leq 1 + b_{su}$, it follows that $n_{ss} > v$, and the lemma is proved for alternative (i).

We now analyze alternative (ii). According to Lemma 2, it must be the case that $h \geq \bar{h}$. Consider an unskilled woman who marries an unskilled man. She receives $y = ½$ and her children's bequest is $b_{uu}$. A skilled man could provide her at least the same utility by choosing $\varepsilon = 1$, $y_{us} = ½$, and $b_{us} = b_{uu} + 1 - h$. She receives the same utility in this scenario as she would if she married an unskilled man, and he gains from it because he marries $v > n_{ss}$ women and raises skilled children. This option is feasible for him since $h \geq 1 + \bar{e}$, and therefore

$$\frac{h + L}{2} > \frac{1 + \lambda}{2} = v\left(\frac{1}{2} + b_{uu}\right) \geq v\left(\frac{1}{2} + \bar{e} + b_{uu} + 1 - h\right) = v\left(\frac{1}{2} + \bar{e} + b_{us}\right).$$

Hence, it cannot be true that skilled men marry fewer women than unskilled men, which completes the proof of the lemma.

PROOF OF PROPOSITION 1:

If $h < \underline{h}$, Lemma 2 implies that all men raise unskilled children. In that case, men are indifferent between skilled and unskilled women, and we denote by $n_{iu}$ the number of women (of either type) that a skilled man marries. Hence, equations (3) and (4) yield

$$\frac{n_{iu}}{v} = 1 + g. \tag{A5}$$

Since all women marry in equilibrium,

$$\theta n_{iu} + (1 - \theta)v = 1.$$

Substituting into equation (A5) yields

$$n_{iu} = \frac{1}{\theta + (1 - \theta)r}, \tag{A6}$$

where $r$ is defined as $1/(1 + g)$. This proves part (i). Part (ii) follows from the fact that $r < 1$. Part (iii) follows immediately from Lemma 2, thus completing the proof.

PROOF OF PROPOSITION 2:

First, we prove part (i). Suppose that there is polygyny and let $\underline{h} \leq h < \bar{h}$. By Lemmas 1 and 2, some skilled men marry skilled women and raise skilled children, and the rest marry unskilled women and raise unskilled children. Since skilled men must be indifferent between the two options, and equation (3) implies that $c$ is the same in both cases, it follows from (2) that

$$n_{ss}(h + b_{ss}) = n_{uu}(1 + b_{uu}). \tag{A7}$$

On the other hand, it follows from equations (3) and (4) that

$$n_{ss}(y_{ss} + \underline{e} + b_{ss}) = (h + L)/2, \tag{A8}$$

$$n_{uu}(y_{uu} + b_{uu}) = (h + L)/2, \tag{A9}$$

and

$$\nu(y_{uu} + b_{uu}) = (1 + \lambda)/2. \tag{A10}$$

Let $p$ denote the proportion of skilled men who marry unskilled women. According to Lemmas 1 and 2 and the equilibrium condition that all women marry,

$$\theta p n_{uu} + (1 - \theta)\nu = 1 - \theta \tag{A11}$$

and

$$\theta(1 - p)n_{ss} = \theta. \tag{A12}$$

Solving equations (3), (4), (5), and (A7)–(A12) yields

$$p = \frac{(1-\theta)[1 - (h - \underline{e})r]}{1 + \theta(h - \underline{e} - 1)}. \tag{A13}$$

Substituting equation (A13) into equation (A12) yields

$$n_{ss} = \frac{1 + \theta(h - \underline{e} - 1)}{(h - \underline{e})[\theta + (1-\theta)r]}. \tag{A14}$$

Equations (A7)–(A9), (A13), and (A14) imply that

$$n_{uu} = n_{ss}(h - \underline{e}) = \frac{1 + \theta(h - \underline{e} - 1)}{\theta + (1-\theta)r}. \tag{A15}$$

Finally, we define the "degree of polygyny" as the average number of women that a rich (skilled) man marries. Thus, from equations (A13)–(A15), the degree of polygyny is

$$\begin{aligned} p n_{uu} + (1-p)n_{ss} &= \frac{(1-\theta)[1 - (h - \underline{e})r]}{1 + \theta(h - \underline{e} - 1)} \cdot \frac{1 + \theta(h - \underline{e} - 1)}{\theta + (1-\theta)r} + 1 \\ &= \frac{1 - (1-\theta)(h - \underline{e} - 1)r}{\theta + (1-\theta)r}, \end{aligned} \tag{A16}$$

which is declining with $h$, thus completing the proof of part (i). Part (ii) follows from Lemma 2.

PROOF OF PROPOSITION 3:

It follows from equation (A14) that $n_{ss}$ is declining with $h$ and reaches $n_{ss} = 1$ as $h$ approaches (from below) $h^* \equiv 1 + g + \underline{e}$. At this point, according to equation (A13), $p$ approaches 0. That is, the number of skilled wives that skilled men marry converges to one, and the number of skilled men who marry unskilled women approaches zero. Correspondingly, each unskilled man marries one unskilled woman, so as $h$ approaches $h^*$, society becomes monogamous. For this to be true, it must be the case that $h^* \leq \overline{h}$. If this condition holds, we show next that for every $h^* \leq h \leq \overline{h}$, monogamy is the only equilibrium.

First, note that if $h^* \leq h \leq \overline{h}$, an equilibrium exists with each man marrying exactly one woman—every skilled man marries a skilled woman and raises skilled children and every unskilled man marries an unskilled woman and raises unskilled children, $b_{ss} = (L - \underline{e})/2$ and $b_{uu} = \lambda/2$. To see that it is unique recall that: (i) Lemma 2 states that for $h^* \leq h \leq \overline{h}$, skilled men who marry unskilled women raise unskilled children, and (ii) the highest number of unskilled women a skilled man could marry is $1 + g$. In that case, he would gain the utility level $\ln[(h + L)/2] + \ln[(1 + g)(1 + \lambda/2)]$, which is smaller than the utility level under the alternative of marrying a single skilled woman and raising skilled children, $\ln[(h + L)/2] + \ln[h + (L - \underline{e})/2]$. Therefore, if $h^* \leq \bar{h}$, there is monogamy for every $h^* \leq h \leq \bar{h}$.

By Lemma 2, the condition that $h^* \leq \bar{h}$ is equivalent to $1 + g + \underline{e} \leq \bar{e} + 1$, implying that $\bar{e} - \underline{e} \geq g$. To show that monogamy does not exist if $\bar{e} - \underline{e} < g$, note that equation (A14) states that $n_{ss} > 1$ in the case that $h^* > \bar{h}$. This completes the proof of Proposition 3.

PROOF OF PROPOSITION 4:

Part (i) follows immediately from Lemma 2. To prove part (ii), let $h > \bar{h}$ and assume by contradiction that there is monogamy. Hence, each unskilled man marries a single unskilled woman and they raise unskilled children. In this case, Lemma 2 implies that $y_{uu} = 1/2$ and $b_{uu} = \lambda/2$. Consider a skilled man who offers an unskilled woman $y_{us} = 1/2$ and $b_{us} = (L - \bar{e})/2$. She is better off, since

$$\ln\frac{1}{2} + \ln\left(h + \frac{L - \bar{e}}{2}\right) - \ln\frac{1}{2} - \ln\left(1 + \frac{\lambda}{2}\right) = \ln\left(\frac{h + L + h - \bar{e}}{1 + \lambda + 1}\right) > 0,$$

where the inequality follows from the fact that $h - \bar{e} \geq \bar{h} - \bar{e} = 1$ and $h + L > 1 + \lambda$. On the other hand, according to equation (3), the number of women he marries, $n_{us}$, is greater than one, since

$$\frac{h + L}{2} = n_{us}\left(\frac{1}{2} + \frac{L - \bar{e}}{2} + \bar{e}\right), \qquad n_{us} = \frac{h + L}{1 + L + \bar{e}} > 1,$$

where the last inequality holds since $h > 1 + \bar{e}$.

Thus, if $h > \bar{h}$, a skilled man could marry more than one unskilled woman and raise skilled children with them, implying that marrying a single skilled woman is not optimal. This proves that monogamy is not an equilibrium, proving part (ii) of the proposition.

From Lemma 2 and part (ii), it follows that all skilled men have skilled children, some with skilled women and some with unskilled women. Since they must be indifferent between the two options, equations (2), (3), and (4) imply that:

$$n_{ss}(h + b_{ss}) = n_{us}(h + b_{us}),$$

$$n_{ss}(y_{ss} + \underline{e} + b_{ss}) = (h + L)/2,$$

$$n_{us}(y_{us} + \bar{e} + b_{us}) = (h + L)/2,$$

$$\nu(y_{uu} + b_{uu}) = (1 + \lambda)/2.$$

Since unskilled women are indifferent between raising skilled children with skilled men and raising unskilled children with unskilled men, it follows that

$$y_{uu}(1 + b_{uu}) = y_{us}(h + b_{us}).$$

Finally, since all unskilled women get married,

$$\theta p n_{us} + (1 - \theta)\nu = 1 - \theta.$$

These equations together with equations (5) and (A12) yield

$$n_{ss} = \frac{1}{1 - p}, \tag{A17}$$

$$n_{us} = \frac{h - \underline{e}}{(h - \bar{e})(1 - p)}, \tag{A18}$$

$$p\theta \frac{h - \underline{e}}{(h - \bar{e})(1 - p)} + \frac{(1 - \theta)r}{(h - \bar{e})^2\left(\frac{1 - p}{h - \underline{e}} - \frac{1}{h + L}\right) - \frac{1}{h + L}} = 1 - \theta. \tag{A19}$$

Since the derivative of the left-hand side of equation (A19) is positive with respect to $p$ and negative with respect to $h$, it follows that $dp/dh$ is positive. Together with equations (A17) and (A18), this proves part (iii), completing the proof of the proposition.

PROOF OF PROPOSITION 5:

First, suppose that $h < \underline{h}$. By Lemma 2, all men raise unskilled children, implying that $y = ½$. Hence, it follows from equations (3) and (4) that $n_{iu}/v = 1 + g$ and the proposition holds. When $\underline{h} \leq h \leq \bar{h}$, Proposition 5 follows immediately from equation (A16), recalling that $r \equiv (1 + g)^{-1}$.

To prove the proposition for $h > \bar{h}$, note that the derivative of the left-hand side of equation (A19) is positive with respect to $p$ and to $r$. Hence, higher inequality (lower $r$) increases $p$. From equations (A17) and (A18), $n_{ss}$ and $n_{us}$ are positively correlated with $p$. Therefore, it follows that the proposition also holds for $h > \bar{h}$.

## Appendix B: A Dynamic Extension of the Model

In this section, we show that our findings carry through to an infinite-horizon, overlapping-generations model. Let superscript $t$ indicate period $t$. In every period, parents choose their children's skill level, $x^t$, and bequest, $b^t$, while taking as given their own skill level, $x^{t-1}$, and initial endowment, $b^{t-1}$. Since the children's inheritance becomes their initial wealth in the next period, parents determine the next generation's human capital and distribution of physical assets, which influences their children's decisions over bequest and human capital investments for their children, and so on.

Suppose that $\underline{h} \leq h < \bar{h}$ and denote the initial proportion of skilled men and women by $\theta^{t-1}$ and the initial endowments of skilled and unskilled men to be $L^{t-1}$ and $\lambda^{t-1}$, respectively. By Proposition 2, skilled women raise skilled children and unskilled women raise unskilled children, regardless of the type of man they marry. Hence, the proportion (and numbers) of skilled to unskilled men and women remain constant over time; that is, $\theta^{t-1} = \theta^t = \theta$.

Let us consider unskilled women first. Some of them marry skilled men and some marry unskilled men. Since they all have the same utility in equilibrium, equation (5) implies that each woman receives $y^t_{uu} = ½$ as consumption and raises unskilled children. Therefore, it must be true that their children receive the same bequest level regardless of whether they married a skilled or an unskilled man. That is, $b^t_{uu} = b^t_l = \lambda^t$, where $b_l$ is the bequest to a boy from two unskilled parents. All skilled women marry skilled men and raise skilled children, implying that all their children receive the same level of bequest, $b^t_{ss} = L^t$. Thus, although there may be polygyny, in the following generation, $t + 1$, there will be the same proportion of two types of men—skilled men with initial endowment $L^t$ and unskilled men with initial endowment $\lambda^t$. Hence, the analysis in the paper is unchanged.

To show that in equilibrium the conjecture that $g > 0$ is satisfied for all $t$, we divide $h$ into two subsegments: $h \in [\underline{h}, h^*)$ where there exists polygyny in equilibrium, and $h \in [h^*, \overline{h})$ where the equilibrium is monogamous. In the first segment, recall that by equation (A7):

$$n_{ss}^t(h + b_{ss}^t) = n_{uu}^t(1 + b_{uu}^t).$$

Since, by equation (A15), $n_{ss}^t < n_{uu}^t$, it follows that, for every $t$,

$$1 + \lambda^{t+1} = 1 + b_{uu}^t < h + b_{ss}^t = h + L^{t+1},$$

which implies that

$$g^t > 0.$$

In the case of monogamy, since unskilled men do not spend resources on raising skilled children, and spend ½ for their own and ½ for their wife's consumption, their bequest necessarily converges to zero. Hence, the total income of unskilled men converges to one. As for skilled men, equations (1) and (3) imply that they bequeath $h - \underline{e}$, which by Lemma 2 is greater than one. Hence, if $h \in [h^*, \overline{h})$, then $g > 0$.

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